International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; SP-9(10): 795-798
www.biochemjournal.com
Received: 13-07-2025
Accepted: 17-08-2025

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Evaluation of IPM modules for the control of white grub in groundnut

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i10Sj.5922

Abstract
The study was conducted to develop effective integrated pest management (IPM) strategies against white grub in groundnut under Kolhapur conditions during 2024-2025. Seven IPM modules combining chemical, biological, cultural, and mechanical approaches were evaluated. Among these, Module 5 (soil drenching with fipronil + imidacloprid at sowing, followed by *Metarhizium anisopliae* application at pegging and pod formation) proved most effective, recording the lowest plant mortality and grub density, while achieving maximum pod (2173 kg/ha) and fodder yield (3214 kg/ha). It also ensured the highest profitability with a benefit-cost ratio of 2.03. Module 4 (clothianidin + *M. anisopliae* + *Heterorhabditis indica*) performed statistically on par with Module 5, whereas Module 2, though less effective, gave the highest incremental cost-benefit ratio due to reduced input costs. The results confirm that integration of chemical seed/soil treatments with entomopathogenic fungi and nematodes enhances both effectiveness and sustainability of white grub management. Such modules reduce pest pressure, improve crop productivity, and ensure economic viability. The findings advocate the adoption of IPM-based modules, particularly Module 5, as a reliable, eco-friendly, and farmer-oriented solution for managing *H. serrata* in groundnut ecosystems.

Keywords: White grub, groundnut, Integrated Pest Management (IPM), *Metarhizium anisopliae*, modules, soil drenching

Introduction
Groundnut (*Arachis hypogaea* L.) is one of the most important oilseed crops, valued for its high oil and protein content as well as its role in soil fertility improvement through biological nitrogen fixation (ICRISAT, 2021) [5]. In India, it contributes significantly to the oilseed economy; however, its productivity is adversely affected by several insect pests, among which white grubs, the larvae of scarab beetles, are highly destructive (Baloda *et al*., 2021) [2]. These soil-dwelling pests feed on roots, pods, and underground stems, causing up to 20-80% yield loss in severe infestations (Yadava & Sharma, 1995) [18]. Even a single grub per square meter can result in complete plant mortality, making them one of the most challenging pests of groundnut.

White grubs, particularly *Holotrichia serrata* (Fabricius), are polyphagous pests widely distributed in India. Their seasonal incidence is closely linked with rainfall, temperature, and relative humidity, with pre-monsoon showers triggering synchronized adult emergence and oviposition (Ranga Rao *et al*., 2010; Patil *et al*., 2024) [14, 13]. Such climatic influences make their management complex, often necessitating integrated and adaptive strategies (Raut *et al*., 2025) [16]. Traditionally, chemical insecticides such as chlorpyriphos, phorate, and imidacloprid have been used for grub management. While effective, indiscriminate chemical use leads to environmental hazards, residue problems, and disruption of natural enemies (Jadhav *et al*., 2020) [6]. This has created a strong demand for sustainable Integrated Pest Management (IPM) approaches that minimize chemical reliance while maintaining effectiveness (Kumar *et al*., 2019) [8].

Biological control has emerged as a cornerstone of IPM against white grubs. Entomopathogenic fungi such as *Metarhizium anisopliae* and nematodes like *Heterorhabditis indica* and *Steinernema* spp. have demonstrated significant efficacy against scarab larvae (Mohi-ud-din *et al*., 2007; Chandel *et al*., 2019) [9, 4]. These agents are host-specific, eco-friendly, and self-sustaining, making them promising tools for long-term

management. When combined with systemic insecticides at critical crop stages, they enhance grub mortality while reducing overall chemical input (Kumar *et al*., 2019) [8]. Cultural practices also form an essential part of IPM modules. Deep summer ploughing exposes pupae and larvae to predation and desiccation, while timely sowing and crop rotation help break the pest cycle (Anonymous, 2020; Yadava *et al*., 2018) [1, 19]. Maintaining field sanitation and conserving natural enemies further supports population regulation. Mechanical and behavioural tools such as pheromone traps provide additional eco-friendly solutions. Synthetic sex pheromone lures effectively monitor and mass trap *Holotrichia* beetles during emergence, significantly reducing their mating success and oviposition (CABI, 2019; Subaharan *et al*., 2017) [3, 17]. When used in large numbers before monsoon rains, they substantially reduce beetle populations, thus lowering larval density in the subsequent crop season (Patil *et al*., 2016) [12].

The integration of these strategies into modular IPM approaches has proven more effective than single interventions. Modules that combine soil application of insecticides at sowing with biological agents at pegging and pod formation stages have been particularly successful, reducing plant mortality and grub density while improving pod and fodder yields (Yadava *et al*., 2018) [19]. Such combinations not only ensure effective pest suppression but also enhance economic viability for farmers.

Materials and Methods

IPM Modules

Seven modules (M1-M7) integrating chemical, biological, cultural, and farmers' practices were evaluated. Modules included seed treatments, soil application of insecticides, entomopathogenic fungi (*Beauveria bassiana*, *Metarhizium anisopliae*), entomopathogenic nematodes (*Heterorhabditis indica*), pheromone traps, and farmers' traditional practices. A control (untreated) was maintained.

IPM module treatments applied against white grub in groundnut

- **M1:** Chlorpyrifos seed treatment + pheromone traps + *B. bassiana* (sowing + 30 DAS)
- **M2:** Chlorpyrifos tree spraying + *B. bassiana* (post-germination + pod formation)
- **M3:** *M. anisopliae* (sowing + peg formation) + *H. indica* (pod formation)
- **M4:** Clothianidin (sowing) + *M. anisopliae* (peg formation) + *H. indica* (pod formation)
- **M5:** Imidacloprid + Fipronil (sowing) + *M. anisopliae* (peg + pod formation)
- **M6:** Farmers' practice (hand collection + chlorpyrifos drenching)
- **M7:** Untreated control

Applications were carried out with a knapsack sprayer (nozzle removed), and appropriate volumes were prepared per plot by mixing biopesticides/insecticides in water.

Data Collection

Observations on white grub damage were recorded at 30, 60, and 90 DAS by counting and removing infested plants. Grub population was assessed at harvest by digging a 1 m² area per plot up to 50 cm soil depth. Yield data (pod and fodder) were recorded from each plot and converted to kg/ha.

Statistical Analysis

Data on grub counts were square-root transformed, and percentage mortality values were arcsine transformed prior to analysis (Panse and Sukhatme, 1967) [10]. Treatment means were compared at the 5% level of significance using Critical Difference (CD).

Benefit-Cost Analysis

Gross and net incomes were calculated based on yield and market price. Benefit-cost ratio (B:C) was derived as gross income / total cost of treatment. Incremental benefit-cost ratio (IBCR) was estimated as additional income over control/treatment cost.

Results and Discussion

Efficacy of different modules against white grub infesting groundnut after application

Field evaluation of different IPM modules revealed significant reductions in plant mortality compared to the untreated control across all observation periods (30, 60, and 90 DAS).

From Table 2 and Fig. 1, At 30 DAS, all treated modules were superior to the control (7.23% mortality). The lowest plant mortality was recorded in Module 5 (2.38%), which was statistically at par with Module 4 (3.46%). Mortality across treatments ranged between 2.38-6.44%. By 60 DAS, differences between modules became more pronounced. Module 5 again proved most effective (6.44% mortality), followed by Module 4 (8.55%). Mortality in other modules ranged from 6.44-24.99%, whereas the untreated control showed 29.22% mortality. At 90 DAS, similar trends persisted. Module 5 recorded the lowest mortality (4.54%), statistically comparable with Module 4 (6.48%). Mortality among the remaining modules varied between 4.54-15.81%, while the control plot showed 24.62% mortality.

Across all stages, Module 5 (soil drenching with fipronil 40% + imidacloprid 40% WG at sowing, followed by two applications of *Metarhizium anisopliae*) consistently achieved the highest efficacy, registering plant mortalities of only 2.38%, 6.44%, and 4.54% at 30, 60, and 90 DAS, respectively. This module also recorded the maximum reduction in plant mortality over control (78.13%). Module 4 (clothianidin + *M. anisopliae* + *Heterorhabditis indica*) ranked next, achieving a 69.73% reduction, followed by Module 3, which reduced mortality by 54.84%.

Overall, the study clearly demonstrates that combining systemic insecticides with entomopathogenic fungi and nematodes provides effective and sustainable management of white grub. Among the tested modules, Module 5 consistently outperformed all others, followed by Modules 4 and 3, while untreated control plots suffered the highest plant losses.

Post-harvest population of white grubs in groundnut fields

Post-harvest observations indicated a significant reduction in white grub populations in all treated modules compared to the untreated control, which recorded 2.54 grubs/m². The lowest density was observed in Module 5 (fipronil 40% + imidacloprid 40% WG @ 250 g/ha at sowing, followed by *Metarhizium anisopliae* @ 5 kg/ha at peg and pod

formation), with 1.05 grubs/m². This was statistically comparable with Module 4 (clothianidin 50% WG @ 250 g/ha at sowing + *M. anisopliae* @ peg formation + *Heterorhabditis indica* @ pod formation), which recorded 1.34 grubs/m².

These results align with Patel *et al*. (2020) [11], who reported that imidacloprid + fipronil and clothianidin treatments significantly suppressed grub populations compared to other modules. Similarly, Mane and Mohite (2014) found *M. anisopliae* more effective than *Beauveria brongniartii* and *B. bassiana* against third instar grubs. Recent findings by More *et al*. (2023) further confirmed that soil drenching with imidacloprid + fipronil and clothianidin provided superior control, with *M. anisopliae* performing as the most effective biocontrol agent among tested fungi and nematodes.

Overall, the integration of systemic insecticides with *M. anisopliae* and *H. indica* proved most effective in reducing post-harvest grub populations, with Module 5 consistently outperforming other modules, followed closely by Module 4.

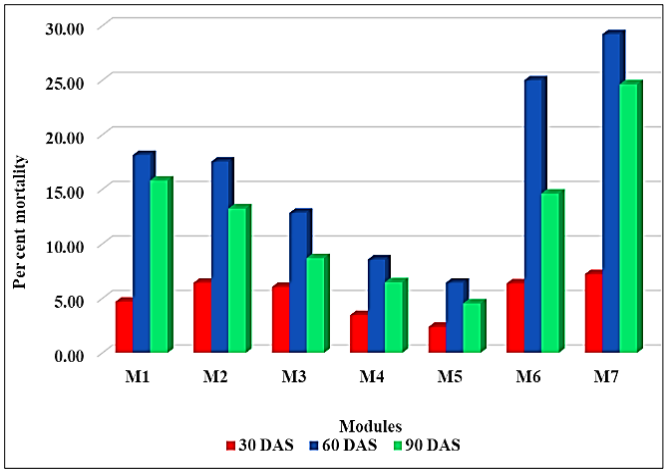

Fig. 1: Efficacy of different modules against white grub infesting groundnut after application

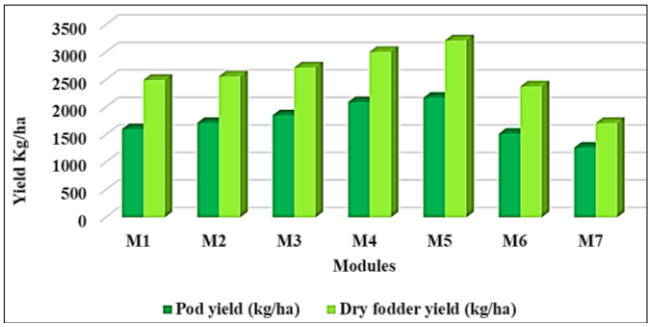

Fig 2: Average yield of groundnut after harvesting (Kg/ha)

Table 1: Overall yield performance of the tested modules

Sr. No.	Modules	Pod yield (kg/ha)	Dry fodder yield (kg/ha)
1	M_1	1601	2495
2	M_2	1716	2561
3	M_3	1854	2723
4	M_4	2092	3006
5	M_5	2173	3214
6	M_6	1518	2378
7	M_7	1265	1712

Table 2: Efficacy of different modules against white grubs infesting groundnut

Sr.no.	Modules	Mean per cent plant mortality (DAS)			Mean	Per cent decrease over control	Avg. no. of grubs/m²
		30DAS	60DAS	90DAS			
1	M_1	4.69 (12.42)*	18.14 (25.16)	15.81 (23.40)	12.88	36.70	3.67 (2.04)**
2	M_2	6.44 (14.68)	17.53 (24.72)	13.23 (21.27)	12.40	39.06	2.33 (1.68)
3	M_3	6.05 (14.09)	12.84 (20.94)	8.69 (17.11)	9.19	54.84	1.67 (1.46)
4	M_4	3.46 (10.70)	8.55 (16.92)	6.48 (14.73)	6.16	69.73	1.33 (1.34)
5	M_5	2.38 (8.84)	6.44 (14.61)	4.54 (12.19)	4.45	78.13	0.67 (1.05)
6	M_6	6.38 (14.60)	24.99 (29.96)	14.61 (22.43)	15.33	24.66	5 (2.34)
7	M_7	7.23 (15.57)	29.22 (32.69)	24.62 (29.70)	20.35	-	6 (2.54)
	S.E.m ±	0.69	1.25	1.14	1.03	-	0.12
	C.D. (5%)	2.13	3.86	3.54	3.18	-	0.38
	CV%	9.22	9.19	9.88	-	-	12.09

*Figures in parenthesis are arcsine transformed values. ** Figures in parenthesis are square root transformed values

Table 3: Incremental Cost-Benefit Ratio of different modules against white grub infesting groundnut

Module No.	Cost of cultivation			Avg. yield (kg/ha)		Additional yield over control		Gross returns			Net profit (Rs/ha)	Additional income over control	B:C ratio	ICBR
	Cost of module treatment	Common cultivation practices	Total (Rs/kg)	Pod	Dry fodder	Pod	Dry fodder	Pod	Dry fodder	Total				
M_1	4170	68230	72400	1601	2495	336	783	108868	3743	112611	40211	24023	1.55	5.76
M_2	2190	68230	70420	1716	2561	451	849	116688	3842	120530	50110	31942	1.71	14.58
M_3	6750	68230	74980	1854	2723	589	1011	126072	4085	130157	55177	41569	1.73	6.15
M_4	11125	68230	79355	2092	3006	827	1294	142256	4509	146765	67410	58177	1.85	5.22
M_5	6750	68230	74980	2173	3214	908	1502	147764	4821	152585	77605	63997	2.03	9.48
M_6	1900	68230	70130	1518	2378	253	666	103224	3567	106791	36661	18203	1.52	9.58
M_7	0	68230	68230	1265	1712	-	-	86020	2568	88588	20358	-	1.29	-

MSP for Groundnut *(Kharif)* for 2024-25 season = 6783 Rs/quintal

Average Yield of Groundnut

From Table 1 and Fig. 2, The evaluation of different IPM modules revealed significant improvements in both pod and fodder yields over the untreated control. Among the treatments, Module 5 (fipronil 40% + imidacloprid 40% WG at sowing, followed by *Metarhizium anisopliae* applications at peg and pod formation) consistently outperformed all others, recording the highest pod yield (2173 kg/ha) and fodder yield (3214 kg/ha). This was closely followed by Module 4 (clothianidin 50% WG at sowing + *M. anisopliae* at peg formation + *Heterorhabditis indica* at pod formation), which produced 2092 kg/ha of pods and 3006 kg/ha of fodder. Module 3 ranked next with 1854 kg/ha pod and 2723 kg/ha fodder yield, followed by Module 2 (1716 and 2561 kg/ha), Module 1 (1601 and 2495 kg/ha), and Module 6 (1518 and 2378 kg/ha). The untreated control (Module 7) recorded the lowest productivity, yielding only 1265 kg/ha pods and 1712 kg/ha fodder. These results clearly indicate that integration of systemic insecticides with entomopathogenic fungi and nematodes, as in Modules 5 and 4, substantially enhances both pod and fodder yields compared to farmers' practices or untreated control.

Cost-Benefit Analysis

From Table 3., Economic evaluation of the IPM modules revealed that Module 5 (fipronil 40% + imidacloprid 40% WG at sowing followed by *Metarhizium anisopliae* at peg and pod formation) generated the highest gross return (₹152,585/ha) with a benefit-cost (B:C) ratio of 2.03, followed by Module 4 (clothianidin + *M. anisopliae* + *Heterorhabditis indica*) with ₹146,765/ha and a B:C ratio of 1.85. Intermediate values were observed in Modules 3, 2, 1, and 6, which recorded B:C ratios of 1.73, 1.71, 1.55, and 1.52, respectively, while the untreated control (Module 7) showed the lowest economic performance (₹88,588/ha; B:C ratio 1.29). Analysis of incremental cost-benefit ratio (ICBR) highlighted that Module 2 (chlorpyrifos tree spraying + *Beauveria bassiana* applications) achieved the highest ICBR (14.58) owing to lower input costs, followed by the farmers' practice (Module 6) with 9.58. In contrast, Module 4 recorded the lowest ICBR (5.22), indicating that while high-input modules ensured greater yields and gross returns, low-cost modules like M2 offered comparatively higher economic efficiency.

Conclusion

The evaluation of IPM modules demonstrated that combining chemical and biological approaches offers effective management of white grubs in groundnut. Module 5, integrating fipronil + imidacloprid with *Metarhizium anisopliae*, consistently minimized plant mortality, suppressed grub populations, and delivered the highest yield and profitability. Thus, integrated strategies, particularly Module 5, present a sustainable option for enhancing groundnut productivity while reducing white grub damage.

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